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A Graphical Analysis of Bundling*

By comparing the demand for a bundle and the vertical sum of the demands for its components, this article analyzes the profitability and welfare consequences of bundling. If it does not lower costs, bundling tends to be profitable when reservation values are negatively correlated and high relative to costs. If bundling lowers costs and costs are high relative to average reservation values, positively correlated reservation values increase the incentive to bundle. Bundling and charging a price equal to the sum of the components' prices lowers consumer surplus. Bundling can, however, increase consumer surplus when it results in lower prices.

I. Introduction

Given its prevalence as a business practice, bundling has received relatively little treatment in the formal economics literature. This neglect may in part be because the explanations for many examples of bundling are too transparent to merit formal treatment. No one questions why shoes are sold in pairs. Virtually everyone who wants a right shoe wants a matching left one, and bundling the two together presumably conserves on packaging and inventory costs. The literature has tended to focus on less transparent cases; its motivation has generally been to provide an alternative to the hypothesis that bundling is a device for leveraging market power from one good to another (see Whinston 1990). The earliest example was Stigler's (1968) treatment of block booking by movie distributors.

Stigler's analysis, as well as Adams and Yellen's (1976), was based on stylized examples with a discrete number of customers. In these examples, the reservation values for the components of the bundle were negatively correlated. That feature made it appear that bundling serves much the same purpose as third-degree price discrimination.

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Schmalensee (1984) advanced the literature considerably toward some generality by considering the entire class of Gaussian demands. A surprising result of his analysis is that bundling can be profitable even when demands are uncorrelated or even positively correlated. His explanation for the profitability of bundling was that it reduces the effective dispersion of reservation values and thereby makes it possible for the seller to extract a greater fraction of the potential surplus.

This article extends the literature on bundling in a number of ways. First, it develops a graphical analysis that clarifies the profitability and welfare consequences of bundling. Second, it takes explicit account of cost savings from bundling. Cost effects interact with demand effects to yield a more sensible set of predictions about the conditions under which bundling is profitable. Third, it derives results that hold for all distributions defined over a finite range. Thus, it makes it possible to examine the sensitivity of Schmalensee's findings to his distributional assumptions.[1] Most notably, it shows that bundling can increase consumer surplus.

The analysis in this article is restricted entirely to what is known as "pure bundling," which is the practice of offering two (or more) goods only in bundled form. Offering two goods both separately and as a bundle (at a price other than the sum of the components' prices) is known as "mixed bundling." Adams and Yellen (1976) argued that mixed bundling at least weakly dominates pure bundling. Their argument presumes, though, that bundling entails no cost savings. Moreover, McAfee, McMillan, and Whinston (1989) have shown that, while (absent cost effects) mixed bundling virtually always strictly dominates pure bundling, the optimal bundle price is sometimes greater than the sum of the prices of the individual goods. Under those circumstances, the optimal mixed bundling policy is only practical if there is some way to prevent people from buying both components separately.

The remainder of this article is organized as follows. Section II introduces the "aggregated components" demand curve and explains why it is the natural benchmark to compare with the bundle demand curve. It then explores the implications of the relationship between the bundle and aggregated components demand curves for the profitability and

1. The Gaussian case considered by Schmalensee (1984) has some attractive features. First, because the sum of two normal distributions is itself normal, the distributions of reservation values for the bundle and the components have the same form. Second, handling correlations between demands for the components is simple. A problem with the normal is, though, that it entails negative valuations. The positive valuations that some people place on the bundle represent the sum of a negative valuation for one component and a larger positive valuation on the demand for the other component. While there may be cases where customers would pay not to receive a good, the assumption of negative valuations is not appropriate whenever an undesirable component of a bundle can be disposed of freely. Because of this limitation, it is particularly important to analyze bundling under different distributional assumptions.

welfare effects of bundling. Section III develops the argument that the incentive to bundle depends in a complicated way on the correlation of demands, the costs of the individual components, and the cost savings from bundling. When bundling does not affect costs, the combination of a negative correlation of reservation values and low component costs creates an incentive to bundle. When bundling does lower costs and component costs are high, however, then bundling is more profitable with positively correlated demands. Section IV contains some concluding comments.

II. The Demand for a Bundle

A. *Effect of Bundling on Demand*

Assume that there are three goods, denoted as good 1, good 2, and M. Goods 1 and 2 are the candidates for bundling and M is an outside good. As has been standard in the bundling literature, assume that each consumer buys either zero or one unit of each of the goods that might be bundled and that the form of the utility function maximized by consumers is

$$u = v_1 D_1 + v_2 D_2 + M. \tag{1}$$

In (1), v_i is a random variable that measures the value consumers place on good i, D_i equals one if a consumer buys a unit of good i and zero if he or she does not, and M is the quantity of the outside good.[2] A key feature of this utility function is that the value a consumer places on one good is independent of whether he consumes the other.[3] It does not, however, have to be statistically independent of the value he or she places on the other.

Let $f(v_1, v_2)$ be the joint probability density function of the valuations. If the two goods are not bundled and p_i is the price of good i, then the demand for good i is given by

$$q_i(p_i) = \int_0^{U_j} \int_{p_i}^{U_i} f(v_1, v_2)\, dv_i dv_j = \int_{p_i}^{U_i} g(v_i)\, dv_i, \quad i = 1, 2, \tag{2}$$

where $g_i(p_i)$ is the density of the reservation values for good i and U_i and U_j are the upper bounds of the ranges of valuations of the two goods. These bounds are assumed to be finite.[4]

2. To derive demand curves based on discrete distributions, a convention is needed for how ties are broken. Assume that the consumer buys good i if $v_i \geq p_i$.
3. See Matutes and Regibeau (1992) for an analysis of bundling when goods are complements.
4. See note 8 below for a discussion of the complications that arise when they are not.

Now, suppose the good is bundled and let $V_B = v_1 + v_2$. The demand for the bundle is given by[5]

$$\begin{aligned} Q_B(P_B) &= \int_{\max[0, P_B - U_2]}^{U_1} \int_{\max[0, P_B - v_1]}^{U_2} f(v_1, v_2)\, dv_2\, dv_1 \\ &= \int_{P_B}^{U_1 + U_2} g_B(V_B)\, dV_B, \end{aligned} \tag{3}$$

where Q_B and P_B are the quantity demanded and price of the bundle and g_B is the probability density function of V_B.

The natural benchmark with which the demand curve for the bundle should be compared is the vertical sum of the component demand curves, which will henceforth be referred to as the "aggregated components" demand curve. When the firm bundles, it necessarily sells the same quantity of the two components. The vertical distance between the demand curve for the bundle and the aggregated components demand curve gives the difference between the price received for a given quantity of the bundle and the sum of the prices from selling an equal quantity of the individual components.

Two examples will serve to illustrate these ideas. In the first, v_1 and v_2 are independently and uniformly distributed over the interval [0, 1] (henceforth, the independent linear demands case). For v_1 and v_2 both between zero and one, $f(v_1, v_2) = 1$. The demand curves for the individual components and the bundle are given by

$$q_i = 1 - p_i, \quad 0 \le p_i \le 1, \tag{4}$$

and

$$\left.\begin{aligned} Q_B &= 1 - \frac{1}{2} P_B^2, & 0 \le P_B \le 1, \\ Q_B &= \frac{1}{2}(2 - P_B)^2 = 1 - \frac{1}{2} P_B^2 + (P_B - 1)^2, & 1 < P_B \le 2. \end{aligned}\right\} \tag{5}$$

To find the vertical sum of the individual components demand curve, solve (4) for p_1 and p_2, impose $q_1 = q_2 = Q_{AC}$, and then solve for $P_{AC} = p_1 + p_2$. Solving the result for Q_{AC} yields

$$Q_{AC} = 1 - \frac{1}{2} P_{AC}, \quad 0 \le P_{AC} \le 2. \tag{6}$$

5. The support of $f(v_1, v_2)$ is a rectangular region. The area of integration for eq. (3) is the area above and to the right of the line $v_1 + v_2 = P_B$. The lower bound of the region of integration for v_1 depends on whether this line intersects the rectangle on the v_2 axis or on the line $v_2 = U_2$. The lower bound of v_2 is the line $v_1 + v_2 = P_B$ when $v_1 \le P_B$ and zero for $v_1 > P_B$. Because the lower bounds of the integrals depend on P_B, the demand curves can have more than one region. See, e.g., eq. (5) below.

The second case is the discrete example in tables 1 and 2. Table 1 gives the joint probability function (f) along with the unconditional probability functions (g_1, g_2) and demand curves [$q_1(p_1)$, $q_2(p_2)$]. The probability function for good 1 (2) is found by summing the columns (rows) of the table. The demand for good i at p_i is simply one minus the sum of the fraction of people who value the good at less than p_i. Table 2 shows the probability function for the demand for the bundle (g_B). The entry of .1 under column head 2 represents the upper left-hand cell of table 1. The entry of .15 under column head 4 of table 2 represents the sum of the upper right-hand cell and the first cell in the second row of table 1. Both types of customers value the bundle at 4. Row 2 of table 2 shows the demand curve for the bundle, which is derived from g_B.

The last row of table 2 shows the aggregated components demand curve. The demands for goods 1 and 2 are 1 at prices of 0 and 2, respectively. For the aggregated components demand curve, therefore, the quantity is 1 at a price of 2, which is the sum of those prices. Similarly, the quantity .75 is for a price of 5 because demands for the two goods are .75 at $p_1 = 1$ and $p_2 = 4$.

Figure 1 pictures the aggregated components demand curve and the bundle demand curve for the independent linear demands case. The curve is the demand curve for the bundle, and the dashed line is the aggregated components demand curve. There are three properties of

TABLE 1 **Joint Density of Reservation Values**

$f(v_1, v_2)$

		v_1, p_1			
	0	1	2	$g_2(v_2)$	$q_2(p_2)$
v_2, p_2 2	.10	.10	.05	.25	1.00
4	.10	.30	.10	.50	.75
6	.05	.10	.10	.25	.25
$g_1(v_1)$:	.25	.50	.25		
$q_1(p_1)$:	1.00	.75	.25		

NOTE.—See text at eq. (6) for explanation.

TABLE 2 **Bundle and Aggregated Components Demand**

	V_B, P_B						
	2	3	4	5	6	7	8
g_B	.10	.10	.15	.30	.15	.10	.10
Q_B	1.00	.90	.80	.65	.35	.20	.10
Q_{AC}	1.00	.75	.75	.75	.25	.25	.25

NOTE.—See text at eq. (6) for explanation.

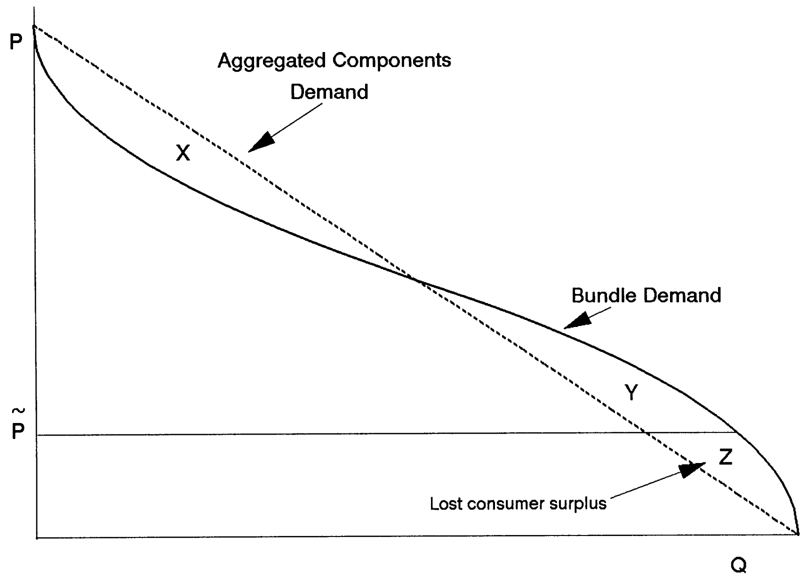

FIG. 1.—Linear independent demand

the relationship between these particular bundle and aggregated components demand curves that are general: (1) the two curves have at least one intersection in the interval $0 < Q < 1$; (2) starting at $Q = 0$ and moving from left to right, the bundle demand curve is below the aggregated components demand curve in the first range where the curves diverge; (3) starting at $Q = 1$ and moving from right to left, the bundle demand curve is above the aggregated components in the first range where the curves diverge.[6]

The first property follows from the following proposition.

PROPOSITION 1. The total areas under the bundle demand curve and under the aggregated components demand curve are equal.

The aggregated components demand curve is created by stacking the demand curve for good 2 on top of the demand curve for good 1. The area under it is therefore the sum of the areas under the individual demand curves, which is the sum of the total valuation that the entire population places on the two goods. The area under the bundle demand curve is the total value consumers place on the bundle. Since the value of the bundle is simply the value of the two component goods, how-

6. To elaborate on property 2, the bundle demand curve might fall below the aggregated components demand curve starting at $Q = 0$. Alternatively, the two curves might coincide for a range beyond which the bundle demand curve drops below the aggregated components demand curve. Similarly, the curves might diverge at $Q = 1$ (and moving toward $Q = 0$), or they might coincide for a region before the bundle demand curve rises above the aggregated components demand curve.

ever, that area also equals the sum of the total valuation of the two goods. If the areas under the two curves are equal, either they coincide or they cross.

The second property follows from proposition 2.

PROPOSITION 2. Consider any Q^* such that $0 < Q^* < 1$. The area to the left of Q^* under the aggregated components demand curve is greater than or equal to the area to the left of Q^* under the bundle demand curve.

As Adams and Yellen (1976) pointed out, one of the welfare losses due to bundling is that the consumers who obtain, say, good 1 as part of the bundle are not the ones who value it most highly. The area under the bundle demand curve is the sum of the total value placed on the two goods by the Q^* customers who place the highest value on the bundle. The area under the aggregated components demand curve is the sum of the total value placed on each good by the Q^* customers who place the highest value on that good. Because the goods are going to those who value them most highly, this area is greater than the area under the bundle demand curve. The areas under the two curves and to the left of Q^* are equal only if the Q^* consumers who place the highest value on good 1 are the same as the Q^* consumers who place the highest value on good 2. If, for all $Q < Q^*$, the Q consumers who place the highest value on good 1 are the same Q consumers who place the highest values on good 2, then the two curves coincide over the range $0 \leq Q \leq Q^*$.

To prove the second property, suppose the two curves do not coincide perfectly.[7] Let (q^*, q^{**}) be the range closest to $Q = 0$ where the two curves diverge, with $0 \leq q^* < q^{**}$. Suppose the bundle demand curve were higher than the aggregated components demand curve in this range. If so, the area to the left of q^{**} and under the bundle demand curve would exceed the area to the left of q^{**} and under the aggregated components demand curve, which contradicts proposition 2.[8]

Together, propositions 1 and 2 imply:

PROPOSITION 3. Consider any Q^* such that $0 < Q^* < 1$. The area to the right of Q^* under the aggregated components demand curve is less than or equal to the area to the right of Q^* under the bundle demand curve.

7. If they do coincide. then it is obvious that properties 2 and 3 both hold (with equality).

8. This argument presumes that the demand curves intersect the quantity axis, and therefore it does not apply to distributions that are defined over an infinite range. The property does hold for the normal and the independent exponential distributions. More generally, proposition 2 holds for distributions with infinite range and finite mean. As q approaches zero, therefore, it would violate proposition 2 if the bundle demand curve were everywhere greater than the aggregated components demand curve. Thus, either this property holds or the two curves continually interweave.

Using the same logic that linked property 2 and proposition 2, the third property follows from proposition 3.

In figure 1, the bundle demand curve and the aggregated components demand curve have a single crossing. This feature is not general. Figure 2 pictures the bundle demand curve and the aggregated components demand curve for the discrete case in tables 1 and 2. Unlike figure 1, there are three interior crossings rather than one. However, the relationship between the two "curves" does have the three general properties described above.

B. *The Effect of Bundling on Profits*

The relationship between the bundle and the aggregated components demand curve is the key to why bundling can be profitable even if it does not lower costs. There are some quantities for which a firm can receive greater revenue by selling the goods bundled than it can by selling them unbundled. Based on propositions 1–3, we can establish some results about when bundling is profitable.

PROPOSITION 4. If bundling does not affect costs, then bundling is profitable only if the profit-maximizing price of the bundle is in the range where bundle demand exceeds the aggregated components demand.

If the profit-maximizing price of the bundle were in a region where aggregated components demand is greater than bundle demand, then the firm could receive greater revenue by selling the same quantity (and thereby incurring the same costs) with components selling. This condition on the profit-maximizing price of the bundle is not sufficient for bundling to be profitable, however, because the optimal quantities under component selling are generally different from the optimal bundle quantity.

The case of independent linear demands illustrates this point. Let c be the common marginal cost of each good. If $c = 0$, then the profit-maximizing price of each component is .5 and the aggregated component price is 1. That price is the point where the bundle demand and aggregated components demand intersect. Thus, bundling and charging a price of 1 would yield equal profits. Because the bundle demand curve is more elastic than the aggregated components demand curve at that point, however, 1 is not the profit-maximizing price of the bundle. Rather, it is $(2/3)^{.5} \approx .816$.[9] At that price, bundle demand exceeds aggregated components demand, which is the necessary condition in proposition 4.

Now suppose that the component cost is .15. If the firm bundles, its profit-maximizing price is $.1 + .7^{.5} \approx .937$. This price is in the range where bundle demand exceeds aggregated components demand. How-

9. A technical appendix that is available from me contains the details of all the derivations and calculations in Secs. II and III.

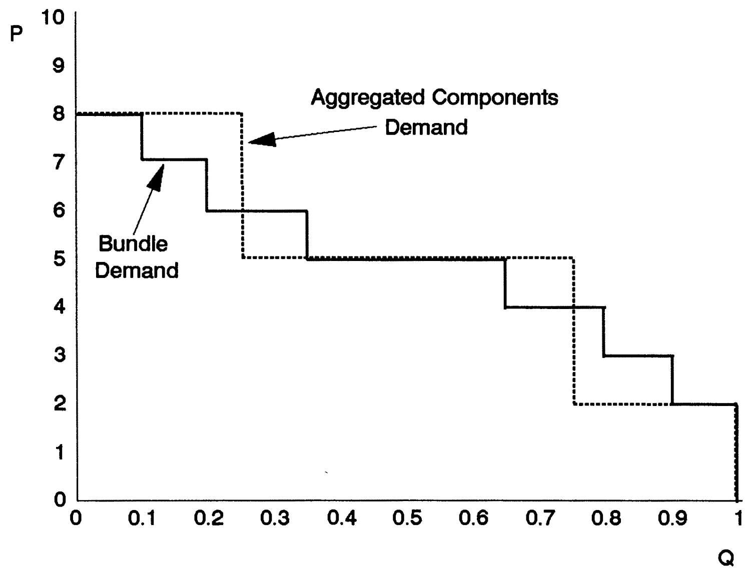

FIG. 2.—Discrete case

ever, the profit-maximizing price of each component is .575. The sum of the prices is 1.15, which is in the range where aggregated components demand exceeds bundle demand. At those prices, profits from component selling exceed profits from bundling.

In this example, bundling is profitable at low cost levels ($c < .138$) and unprofitable at high cost levels. There is a related general proposition:

PROPOSITION 5. Suppose that bundling does not affect costs. Whenever bundling is strictly profitable, there is an increase in the cost of the components that makes it unprofitable.

Let Q' be a profit-maximizing quantity of the bundle when bundling is strictly profitable. From proposition 4, the bundle demand curve lies above the aggregated components demand curve at Q'. From property 2 of the relationship between the bundle and aggregated components demand curve, the area under the aggregated components demand curve and to the left of Q' is greater than the area under the bundle demand curve and to the left of Q'. Thus, there must be some $Q'' < Q'$ for which the aggregated components demand curve is above the bundle demand curve. There is some increase in cost that would make Q'' the best possible bundle output. Given those costs, components selling would yield higher profits than bundling.[10]

10. Proposition 5 does not imply that an increase in the costs of the components always makes bundling less profitable. It is easy to construct examples in which bundling is profitable at one level of costs and unprofitable at lower levels.

C. *Effects on Consumer Surplus*

The relationship between the aggregated components and bundle demand curve makes it possible to show graphically the effects of bundling on consumer surplus. In figure 1, $\tilde{P}$ is an arbitrary price level. It represents both a bundle price and a sum of components prices that imply equal sales of each component. The difference in consumer surplus between components selling and bundling is $X - Y$.[11] Because the areas under the two demand curves are equal, $X = Y + Z$. At a constant price level, therefore, bundling lowers consumer surplus by Z.[12] In general, though, the optimal bundle price is different from the sum of the optimal components prices. Thus, we can decompose the effects of bundling on consumer surplus into the "pure bundling effect" described above and a "price effect." When the bundle price is higher than the sum of the components prices, the price effect reinforces the pure bundling effect. When it is lower, the pure bundling and price effects go in opposite directions.

For Gaussian demands, Schmalensee (1984) found that bundling always lowers consumer surplus. In the case of independent linear demands, however, bundling increases consumer surplus whenever costs are low enough for bundling to be profitable.[13] Thus, the effect of bundling on consumer surplus depends on the precise distribution of reservation values.

III. Correlation of Demands and Cost Savings from Bundling

Bundling reduces the effective variation in reservation values more when demands are negatively correlated. In the extreme where reservation values are perfectly negatively correlated, all consumers have the same reservation value for the bundle. If, in addition, both marginal costs are below everyone's reservation values, the firm can then ex-

11. Using the aggregate components demand curve to measure welfare with components selling presumes that equal quantities of the two goods would be sold.

12. Since $X - Y = Z$, it is obvious that $X - Y$ is positive. If P were above the intersection of the two curves, then the lost consumer surplus would be a single area above the demand curve and would also clearly be positive. See figure 4 below. With multiple intersections, the change in consumer surplus cannot always be represented as a single area. Holding price constant, however, bundling always lowers consumer surplus even if it increases output. To see that this is so, suppose that the price level is also marginal cost. In that case, the outcome with components selling is a welfare optimum. Any deviation from that outcome lowers welfare and, if profits are zero, consumer surplus as well.

13. One might suspect that the negative valuations in the Gaussian case "bias" the analysis toward finding that bundling lowers consumer surplus. While this might be part of the explanation, bundling causes consumer surplus to drop for some distributions that are defined over only positive values. The discrete example is one such case. An appendix available from me examines the case of independent exponential demands. There, bundling causes the price to drop, but the pure bundling effect dominates.

tract all of the potential surplus in the market. While there is no general proposition that the incentive to bundle is a decreasing function of the correlation between reservation values, the incentive tends to be strongest for negatively correlated demands provided that costs are low.

When bundling lowers costs, it can be profitable under a much different set of circumstances. To see that this is the case, we need to create correlation among the reservation values. One way to do so is to assume that the demand for each good is the sum of two components, one that is common between the two goods and one that is idiosyncratic. If the common component enters the reservation value for both goods positively, then the reservation values are positively correlated. If it enters one positively and one negatively, then they are negatively correlated. The magnitude of the correlation is adjusted by changing the relative size of the common and idiosyncratic components. If the distribution of each component is uniform, then closed-form solutions for all of the relevant demand curves exist. Formally, the assumption is

$$v_i = w_i + \frac{1-\alpha}{2} + D_{ij}\left(u - \frac{1-\alpha}{2}\right), \quad i = 1, 2, \quad j = P, N, \qquad (7)$$

where w_i, the idiosyncratic component of the valuation of good i, is distributed uniformly over the interval $[0, \alpha]$; u, the common component of the valuation, is uniformly distributed over the interval $[0, (1 - \alpha)]$; and $D_{1N} = D_{1P} = D_{2P} = 1$ and $D_{2N} = -1$. The variable α ranges from zero to one.[14]

Despite the simplicity of these assumptions, the demand curves are quite messy and are not presented here.[15] However, the most important point from this analysis can be seen graphically. In figure 3, demands are highly negatively correlated. If the bundle costs C to produce, then bundling reduces profits to zero.[16] No one values the bundle as much as it costs to produce. The variable P_{AC} is the sum of the components' prices, and the top shaded area is the profits from components selling. Figure 3 also shows another cost level, C', and the associated profit-maximizing bundle price, P'_B. The lower shaded area is the profits from bundling with these costs. The variable C' was chosen so that the profits from bundling equal the profits from component selling with costs of C. Given these negatively correlated demands, a cost reduction of $C - C'$ would be needed to induce the firm to bundle.

14. The form of eq. (7) insures that the total value placed on each good is 1/2 regardless of α. The third term is expressed as a deviation from the mean, so it has a mean of zero. The first term has a mean of $\alpha/2$. Adding that to the second term, which is a constant, gives 1/2.

15. They are relegated to the technical appendix mentioned in n. 9 above.

16. In this case, $\alpha = .25$, and $C = 1.4$.

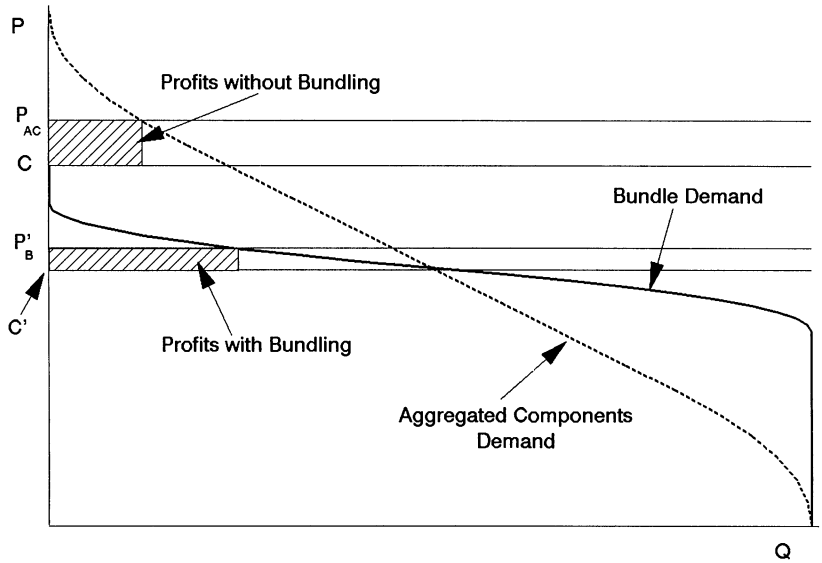

FIG. 3.—Negatively correlated reservation values

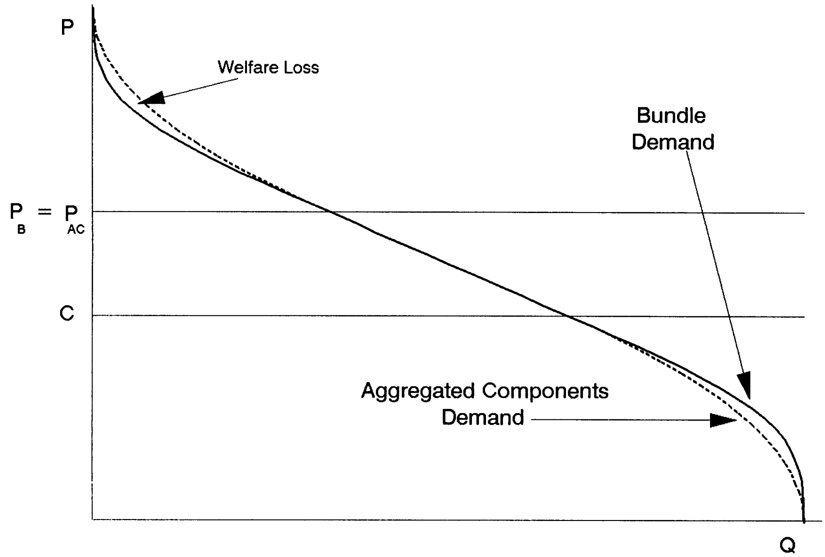

FIG. 4.—Positively correlated reservation values

In contrast, figure 4 pictures a case with positively correlated reservation values. The bundle demand curve and the aggregated components demand curve coincide over a substantial range. The cost level C is such that the profit-maximizing prices are in this range. If bundling does not affect costs, then the bundle price equals the sum of the components' prices, and profits are the same. In this case, any cost saving from bundling, no matter how small, induces the firm to bundle.

With the same degree of positive correlation, still higher costs would induce the firm to price in the range where the demand curves do not coincide. Under such circumstances, a larger cost saving would be necessary to cause the firm to bundle. If the demands were still more highly correlated, however, the range of coincidence would be larger. As a result, there would be a larger range of costs for which an infinitesimal cost saving would induce the firm to bundle. It is in this sense that high positive correlations make bundling more likely when bundling entails cost savings.

When there are no cost savings from bundling in figure 4, the identity of the purchasers depends on whether the firm bundles even though the total quantity sold does not. The associated welfare loss from the inefficient distribution is the area between the two demand curves and above the line $P = P_B = P_{AC}$. In combination with the welfare analysis from the previous section, this result suggests that the effect of bundling on consumers is complicated and counterintuitive. It is theoretically possible for bundling to lower welfare even though the firm's sole motivation is to lower costs and prices. In contrast, bundling might benefit consumers when the motive is to reduce the variation in reservation values and thereby extract a greater fraction of the available rents.

IV. Conclusions

Demand-based/price discrimination explanations have played a prominent role in the economics literature on bundling. As interesting as the analysis might be, one might question the empirical relevance of the theory that bundling occurs to reduce the variation in reservation values and thereby allow a monopolist to extract a greater fraction of the available surplus.[17]

17. The cable television industry may be one industry where this explanation is appropriate. Basic cable television service is sold as a bundle. There are three key features of the market that support the conjecture that bundling in this industry is demand-based. First, virtually all cable television markets have at least historically been served by monopolists. Second, the mix of offerings in the basic tier in most areas is quite diverse. As a result, the reservation values for the different classes of channels may be relatively uncorrelated and, for some pairs of networks, negatively correlated. Third, the marginal cost of providing a channel to an additional subscriber is very low. For another perspective on bundling in the cable television industry, see Wildman and Owen (1985).

This article has presented an analysis of bundling that combines both cost and demand effects. The result is a model that yields more realistic predictions for when bundling occurs. When bundling lowers costs, it tends to be more profitable when demands for the components are highly positively correlated and component costs are high. This finding is in distinct contrast to the purely demand-based analysis of bundling, in which the practice tends to be most profitable when component costs are low and demands are negatively correlated.

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